AIRCRAFT ICING (AI)

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January 15, 1999

http://www.icebox.lerc.nasa.gov/

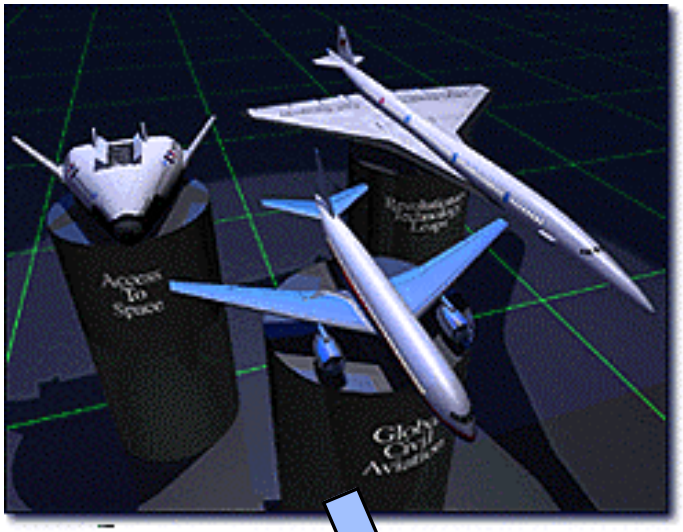
OUTLINE & LIST OF FIGURES

ACRONYMS & ABBREVIATIONS

- AEDC - Arnold Engineering Development Center
- AES - Atmospheric Environmental Services
- AGATE - Advanced General Aviation Transport Experiment
- AI - Aircraft Icing
- ALPA - Airlines Pilots Association
- AOC -
- AOS - Aviation Operations Systems
- ATM -
- CIRA - Centro Italiano Recerche Aerospazialli
- COMET - Cooperative Program for Operational Meteorology, Education & Training
- CRREL - Cold Regions Research Engineering Lab
- DER - Designated Engineering Representative
- DERA - Defence Establishment Research Agency
- DOD - Department of Defense
- FAA - Federal Aviation Administration
- FAR - Federal Aviation Regulations
- GA - General Aviation
- INTA -
- IP - Ice Protection
- IPS - Ice Protection System
- LSWT - Low Speed Wind Tunnel
- LTPT - Low Turbulence Pressure Tunnel
- MIT - Massachusetts Institute of Technology
- NCAR - National Center for Atmospheric Research
- NOAA - National Oceanic and Atmospheric Administration
- NRC - National Research Council of Canada
- ONERA -
- SBIR - Small Business Innovative Research
- SLD - Supercooled Large Droplets
- STTR -
- TIP - Tailplane Icing Program
- UIUC - University of Illinois Urbana-Champaign
- WSU - Wichita State University
- W.T. - Wind Tunnel

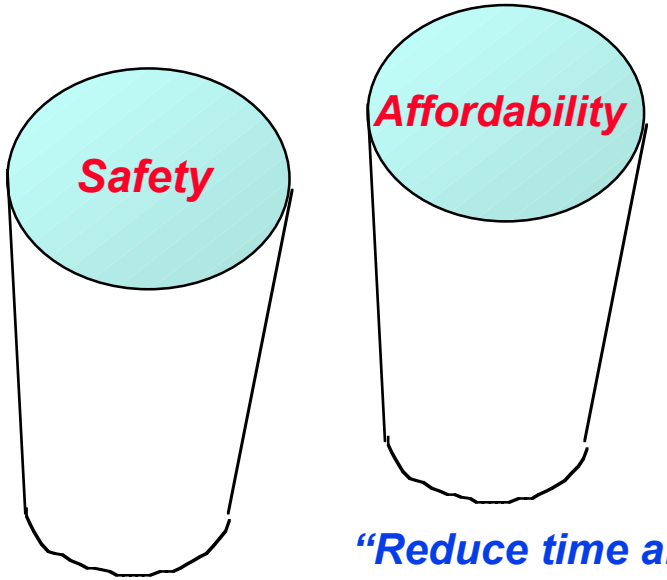
GOALS

NASA's Aeronautics & Space Transportation Technology: Three Pillars for Success



Pillar One: Global Civil Aviation

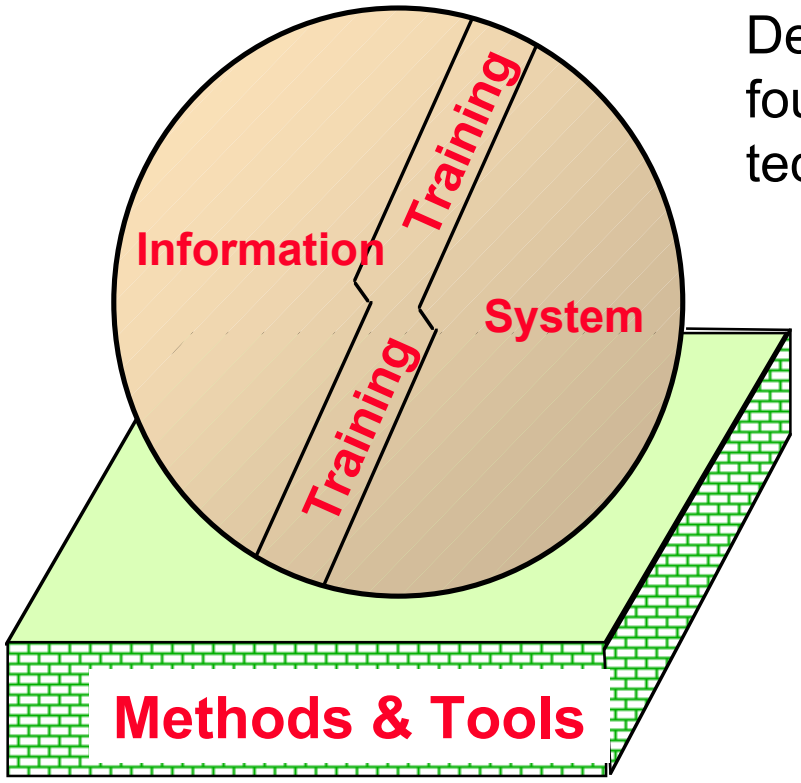
Aircraft Icing Research



"Reduce accident rates due to icing hazards"

"Reduce time and cost of design and certification of icing systems"

OBJECTIVES



Develop methods and tools as the foundation to provide information and technology solutions for the aviation system.

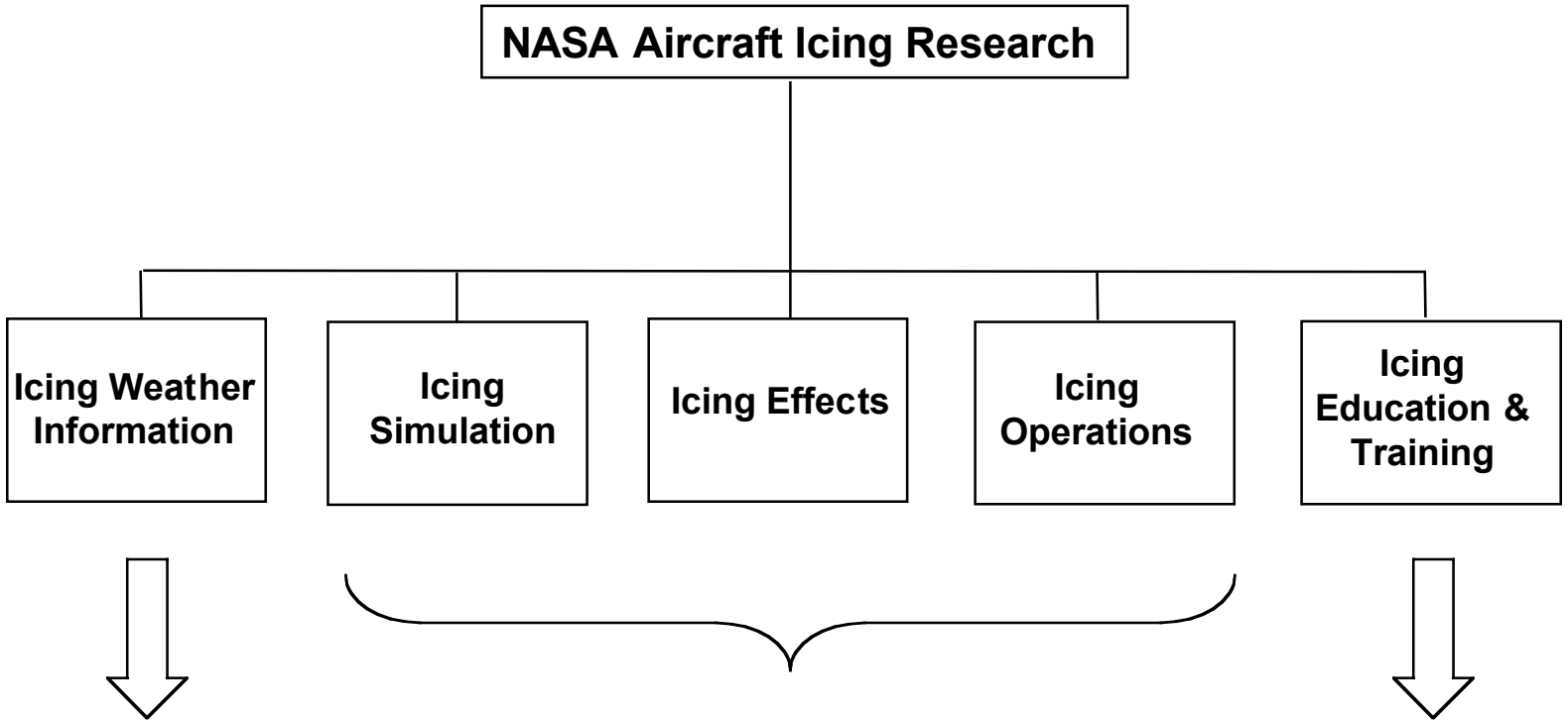
❶ Reduce cost and time for design and certification of icing systems
❷ Train pilots and operators to use information and systems in the safest manner
❸ Develop aircraft systems for all icing weather operations
❹ Provide icing weather information to cockpit, AOC, and ATM

The training aids link how the information is managed in the system.

PROJECT APPROACH

AI

Major Technology Elements



OBJECTIVE (4): Info to pilots/dispatchers

OBJECTIVES (1) & (3): Reduce cost & time for cert.; All-Weather Aircraft

OBJECTIVE (2): Safe & proper use of info/systems

DELIVERABLES

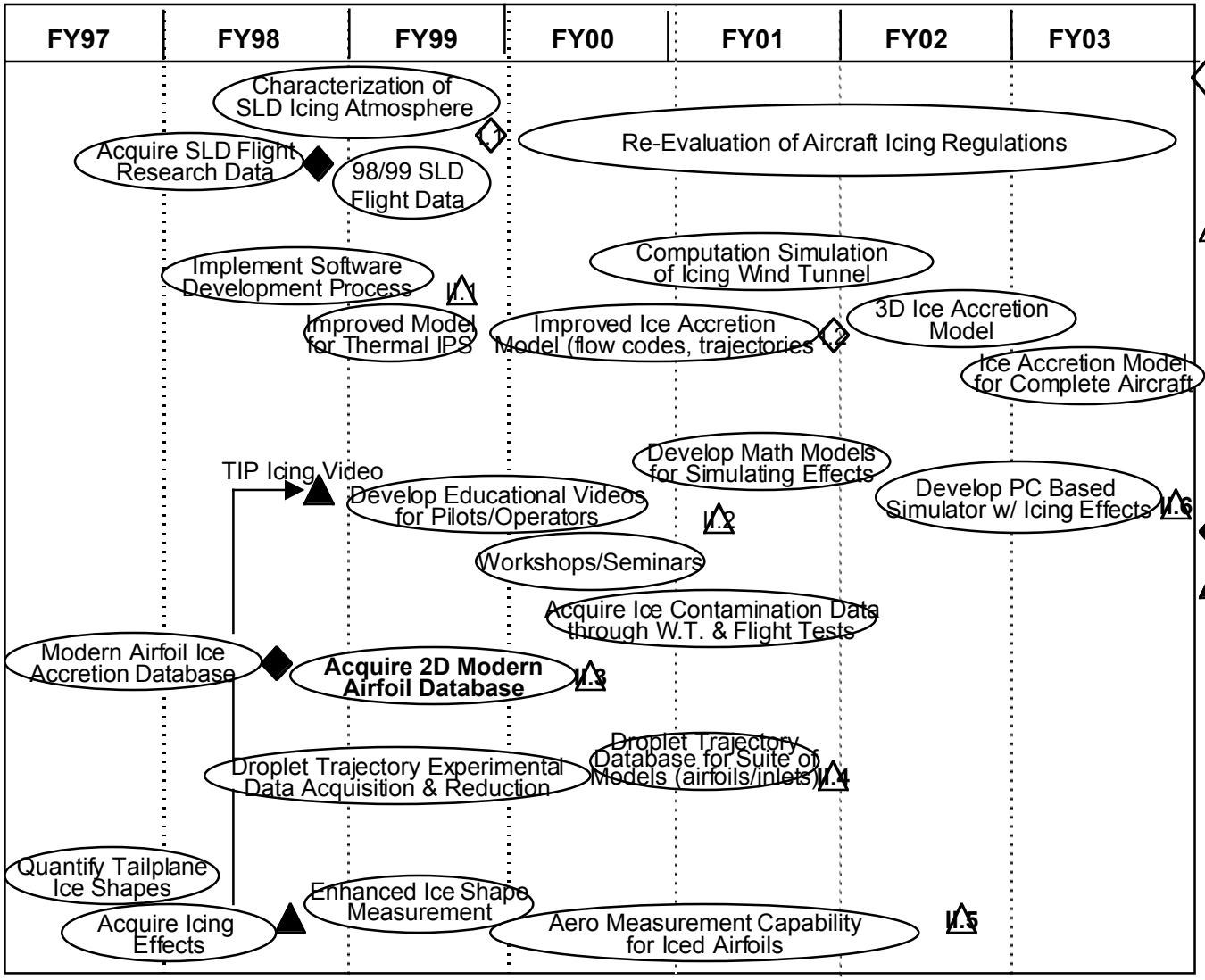
- Icing Weather Information
  - Atmospheric Characterization: Provide to regulatory agencies data acquired and analyzed from flight tests for purposes of evaluating icing certification envelopes (See Lev I and Lev II milestones)
  - Weather Products: With meteorological research organizations, develop and implement icing weather forecast models
- Icing Simulation
  - Computational Methods: Improve ice accretion and ice protection system prediction methods thus allowing use of codes for design and certification over a range of icing conditions, aircraft geometries and flow conditions (See Lev I and Lev II milestones)
  - Experimental Methods: Develop improved capabilities and innovative methods to represent natural ice growth, quantify ice feature characteristics, measure effects of icing on aircraft performance, and evaluate Ice Protection Systems in a controlled environment
  - Scaling: Improve and extend icing scaling capabilities to a broader range of icing conditions including near freezing temperature applications and over a range of icing facilities

DELIVERABLES (Cont.)

- Icing Effects: Develop techniques to represent the effects of ice contamination on aero characteristics and to quantify the impact on performance, stability, controllability and handling qualities (See Lev II milestones)
- Icing Operations: Develop techniques allowing aircraft to avoid icing conditions and/or tolerate icing conditions
  - Icing Avoidance
    - Ensure on-board weather systems include icing weather information
    - Develop and field test ground-based and airborne icing conditions remote sensors (See Lev III milestones)
- Icing Education & Training
  - Education Material: Develop educational videos for increasing pilot awareness of icing hazards incl. Tailplane Icing, Supercooled Large Droplets and Icing Primer (See Lev. II milestones)
  - Simulator Development: Provide pilots with ground-based demonstrator that will supply realistic simulation of an in-flight icing encounter (See Lev II milestones)
  - Pilot/Dispatcher Training: Produce interactive module for pilots and dispatchers that include key icing weather factors and issues

ROADMAPS & MILESTONES

AI



Project Funding

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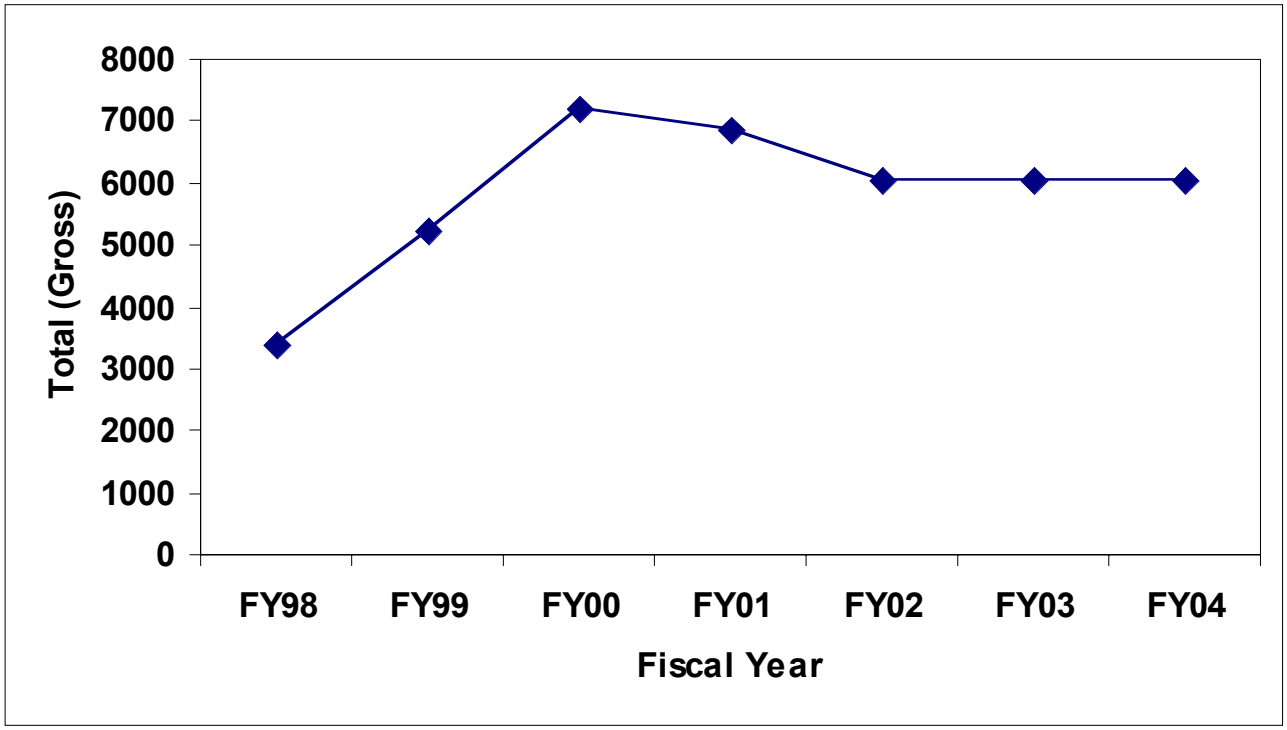
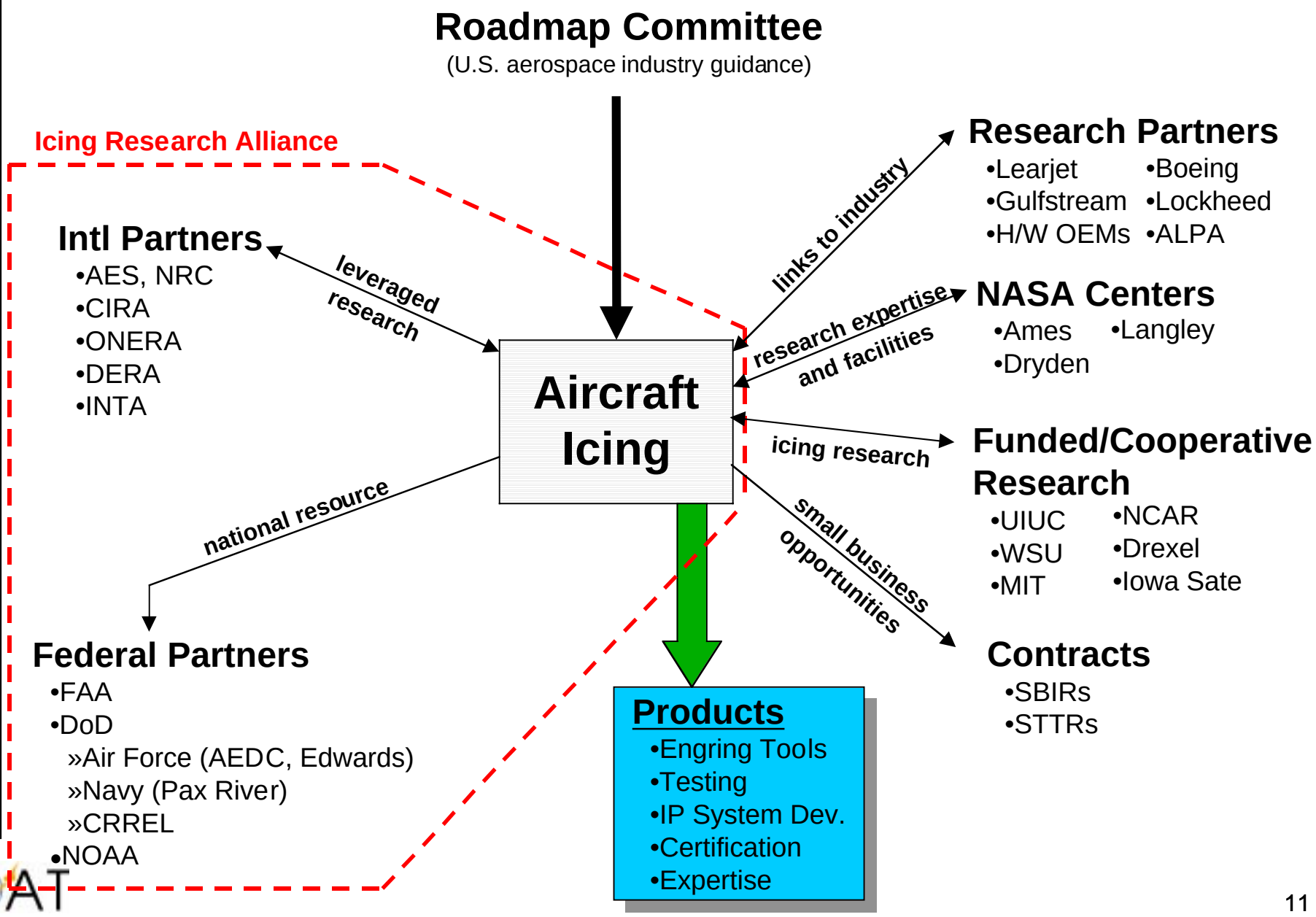


Nov-99	FY98	FY99	FY00	FY01	FY02	FY03	FY04	Total
Net Totals	2379	3772	5222	5033	4565	4574	4574	30119
Program Support	984	1466	1975	1826	1472	1463	1463	10649
Total (Gross)	3363	5238	7197	6859	6037	6037	6037	40768

Outside Relationships

AI



TECHNOLOGY TRANSFER

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Product	Standards & Requirements	Partners	Customers
LEWICE	Icing Certification FAR Part 23 And 25	UIUC	Numerous Industry incl. FAA DERs
Icing Research Tunnel (Develop-ment/Certification)	FAR Parts 25, 29 (1) Appendix C (2) Ice Protection System Perf.		Numerous Industry, e.g., Sikorsky S-92, Bell Helicopter 609, Bom-bardier Global Express
Icing Training Aids • Videos (e.g., TIP) •Computer based icing weather training module •Desktop simulators	FAA Flight Standards	FAA, ALPA, WSU	GA Pilots, Regional Pilots, Large Transports
SLD Database	Exceedance Conditions	FAA, AES, NCAR	Airline Operators
Consulting •Icing Expertise •Computational Assets	Safety, Certification Stds		FAA, DOD, Aerospace Industry

MAJOR ACCOMPLISHMENTS (FY98)

AI

- AOS Lev I Milestone: Complete Icing Tunnel Database of Ice Shapes for Modern Airfoils (6/98)
  - 2D ice shapes obtained and catalogued for large transports, business jets and GA aircraft
  - Database will be used for ice shape prediction, code verification and validation, and guidance for ice protection system design
- AOS Lev I Milestone: Complete NASA/FAA/NCAR SLD icing flight program (9/98)
  - Completed NASA/FAA/NCAR Supercooled Large Droplet 97/98 icing flight testing
  - Data analyzed to better characterize SLD clouds and to improve forecasting models
  - Data presented to FAA for regulatory material review and NCAR for weather prediction tool development
- AOS Lev I Milestone: Complete flight test and instrumentation comparison for the NASA/AES joint supercooled large droplet icing program (4th Q, 99)
  - Completed wind tunnel entry wherein numerous cloud characterization instruments were tested in a controlled/repeatable environment
  - 98/99 flight tests planned; AES collaboration on instrumentation and data acquisition, reduction and analysis

MAJOR ACCOMPLISHMENTS (FY98)

AI

- AOS Lev I Milestone: Release computational prediction tool LEWICE Ver. 3.0 to industry
  - Development of code requirements, standards and acceptance criteria on-schedule
  - Configuration management concerns (e.g., version control, distribution policies) being established
- AI Lev II Milestone: LEWICE Ver. 2.0 Release
  - Icing physics (roughness, heat transfer, transition) improved via grants with UIUC, Iowa State, and Drexel
  - Completed validation activities including ice shape computational methods, comparison of computed and experimental ice shapes and expansion of experimental database
- AI Lev II Milestone: Release 2nd series of icing pilot training videos
  - Task review held with Cooperative Program for Operational Meteorology, Education & Training (COMET); Training module development requirements finalized
  - Established gov't/contractor team including Ames/Lewis/COMET
  - Completed AGATE funded GA survey for icing training needs assessment

MAJOR ACCOMPLISHMENTS (FY98)

AI

- AI Lev II Milestone: Complete Tailplane Icing Program (Phases 1 and 2)
  - TIP I Final Report released
  - TIP educational video released; 250 copies distributed (150 copies to FAA flight standards)
  - Cooperative effort initiated with Learjet for Phase 2 related tailplane icing test in the IRT and full scale aero effects testing in the ARC 40X80
- AI Lev II Milestone: Provide GA/Commuter community a PC-based simulator and training module for icing effects in light aircraft
  - Signed grant with Wichita State University to develop experimental database and 6 degree-of-freedom nonlinear mathematical model required for training simulator
  - Military trainer sub-scale aircraft tested in Wichita State University 7X10 LSWT and Birhle Applied Research vertical flow tunnel to determine viability of measuring ice contamination levels on very small subscale models

OTHER ACCOMPLISHMENTS (FY98)

AI

- Experimental Methods
  - Continued further development of hybrid airfoil test techniques
  - Implemented 3D laser scanner for ice shape quantification
  - Leading "Facility Comparison Test", a comparison of the performance of 8 ground simulation facilities in North America and Europe; completed IRT test
- Icing Effects
  - Continuing effort with UIUC to quantify ice contamination induced roll upset; work being performed for FAA and AGATE
- Icing Operations (Avoidance)
  - NASA AGATE contract with NCAR to examine icing weather information in the GA cockpit
  - Grant with MIT for human centered design approach to examine integrated cockpit icing weather information systems
- Icing Operations (Remote Sensing)
  - Interagency Agreements signed with:
    - CRREL for planning and meteorological requirement definition
    - Hanscom AFB for simulator code development
  - Contract/SBIR/STTR signed with:
    - SPEC/NCAR for satellite system assessment
    - TSC for airborne radar assessment
    - Raytheon for radiometer assessment

AI FACILITY UTILIZATION

- FY99
  - LeRC Icing Research Tunnel
  - LeRC Icing Research Aircraft (Twin Otter)
  - LaRC LTPT
  - ARC 40X80 LSWT
  - Wichita State Univ. 7X10 LSWT
  - Ohio State University 7X10 LSWT
  - BF Goodrich Ice Protection Systems Division Icing Wind Tunnel
  - Boeing Research Aerodynamic Icing Tunnel
  - Cox & Co. LeClerc Icing Research Tunnel
  - Birhle Applied Research Large Amplitude Multi-Purpose Facility
- FY00
  - LeRC Icing Research Tunnel
  - LeRC Icing Research Aircraft (Twin Otter)
  - Boeing Research Aerodynamic Icing Tunnel
  - Wichita State Univ. 7X10 LSWT
  - Other (Unspecified) Low Speed Wind Tunnels

Project Assessment

AI

	3Q98	4Q98	1Q99	Remarks
Program Overall Assessment	G	G	G	
Technical Performance	G	G	G	
Cost	Y	G	G	Costing of Grants caused cost variance; Corrected by end of FY
Schedule	Y	G	G	SLD data reduction caused delay in completion of SLD flight program Lev II milestone; Corrected

Guidance:

Assessment & Performance	*L2 Judgement*
Cost	*-5% Yellow* *-15% Red*
Schedule	*-1Q Yellow* *-2Q Red*

FUTURE FY 99 Activities

AI

- Icing Weather Information
  - SLD flight tests to start 1/99 w/ NCAR/AES; continue data reduction and analysis for regulation review and weather prediction tool development
  - Hold workshop (Summer 99) on SLD instrument comparison test results; continue assessment and cross-comparison of instruments
- Icing Simulation
  - Completion of software re-engineering and release of LEWICE 2.0; initiation of new icing physics models for LEWICE 3.0
  - Facility Comparison Test: lead effort to quantify comparison of test results from multiple facilities to see how well ground simulation facilities produce ice accretion shapes under identical test conditions
  - Continue to develop and refine methods for performing valid scale model icing tests
- Icing Effects
  - Tailplane icing effort will concentrate on icing tests (2nd Q 99) and low speed wind tunnel tests (4th Q 99) of Learjet 45 horizontal stab; Results will establish relationship between full- and scale-model testing
- Icing Operations
  - Complete remote sensing system requirements; identify concepts for ground-based measurement and detection systems
  - Multi-agency experimental validation database test at Mt. Washington
- Icing Education and Training
  - Produce training videos, “Icing Primer” and “SLD Icing”
  - Continue development of experimental database from wind tunnel performance data for training simulator

SUMMARY

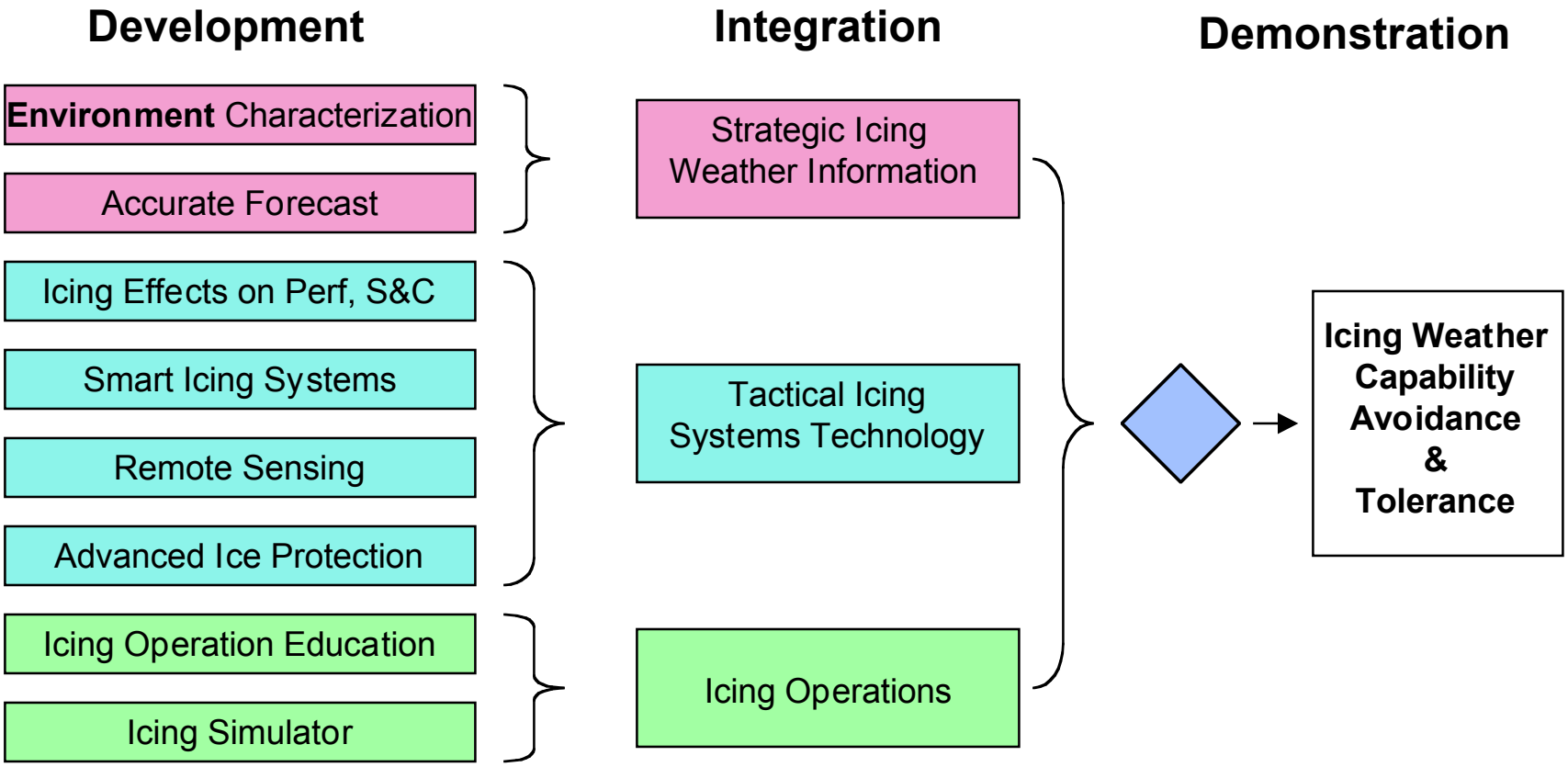
- Aircraft Icing project strongly linked to Global Civil Aviation pillar and safety related goals
- Project management metrics (cost, schedule, performance) are all positive (green)
- Project has been re-scoped to make AI more relevant to Code R, and to the needs of the aeronautics community, e.g., icing weather tasks, pilot training development
- Project has entered into significant relationships with a multitude of domestic and foreign organizations with positive benefits to Code R and to aviation safety
- The Icing Research Alliance has been defined in concept and a steering committee formed to startup, structure and charter the alliance
- Most significant threat to the project continues to be a workforce shortfall; struggling to meet commitments with current (and projected) civil servant staff

Backup Slides

PROJECT APPROACH

AI

Develop technology elements and integrate at system level to demonstrate readiness needed to address key elements of icing flight safety



Workforce Profile

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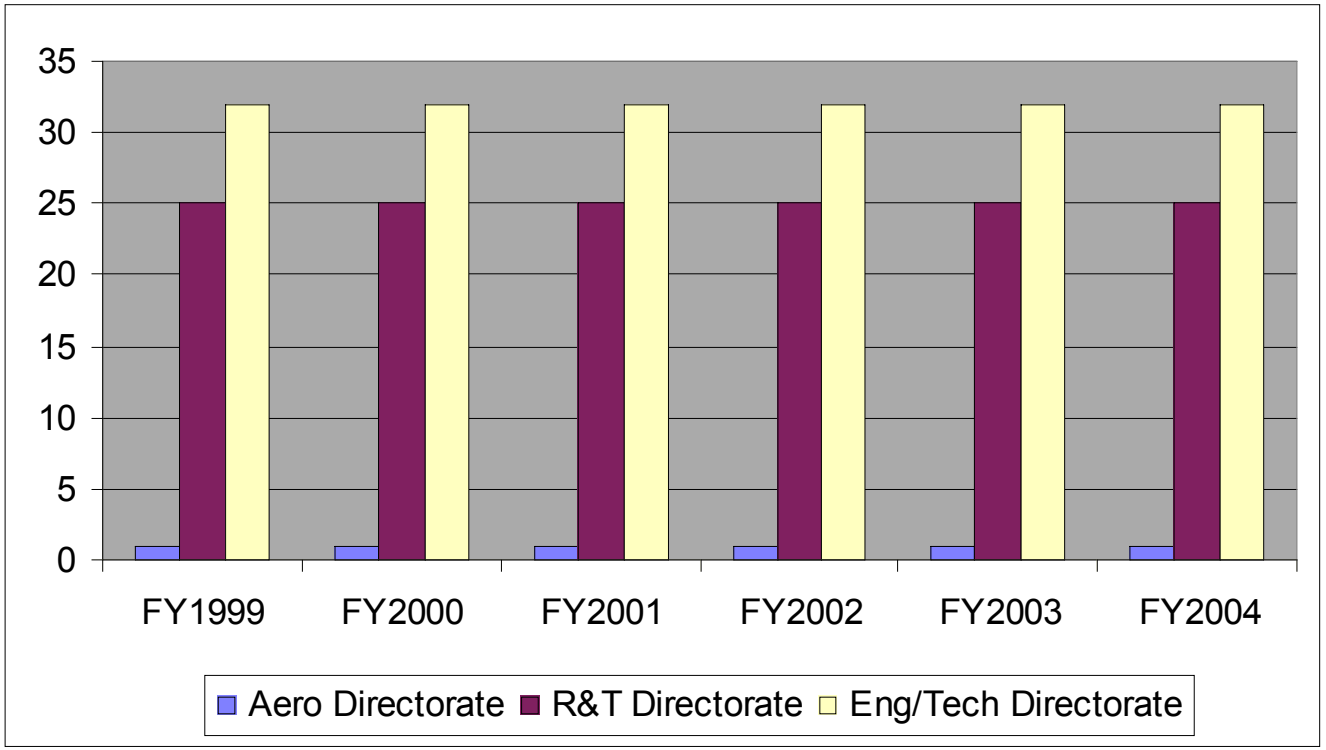
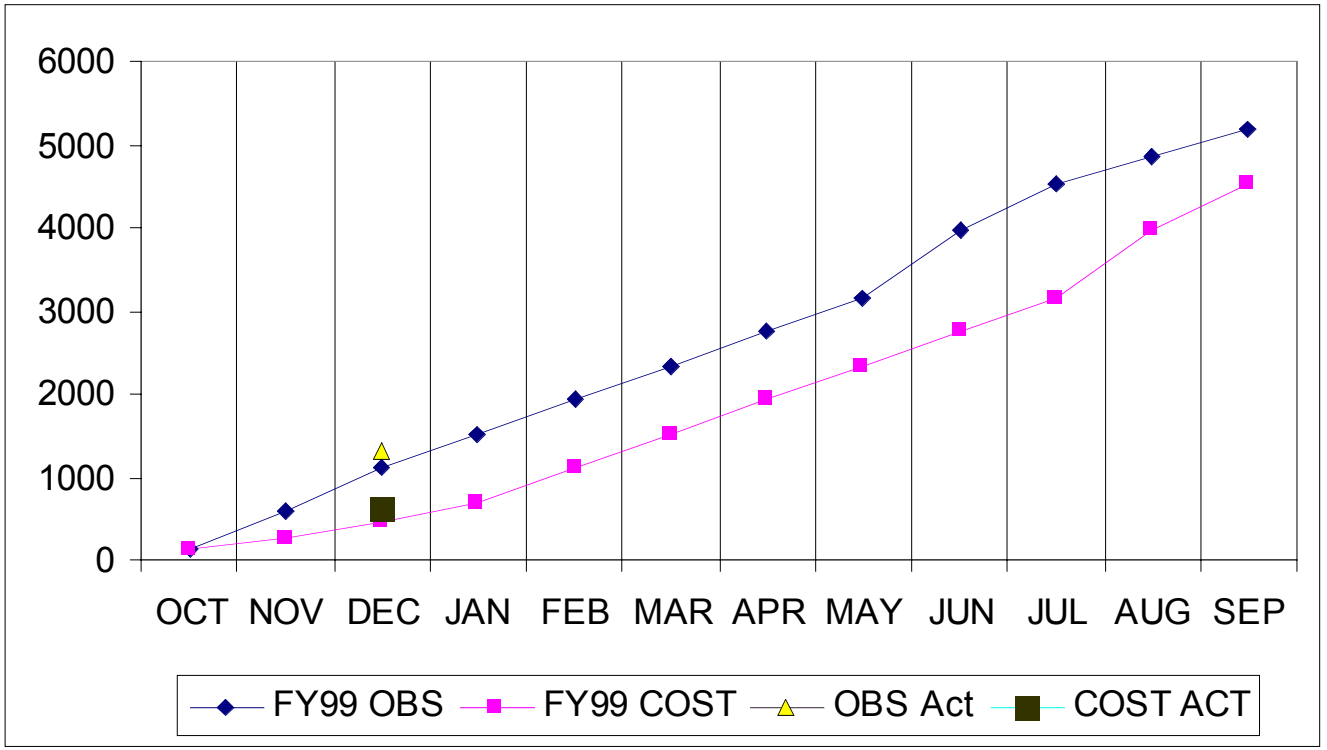


Directorate	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004
2000	1	1	1	1	1	1
5000	25	25	25	25	25	25
7000	32	32	32	32	32	32
TOTAL	**58**	**58**	**58**	**58**	**58**	**58**

FY99 FINANCIAL PERFORMANCE

AI



PLAN	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
FY99 OBS	134	584	1099	1510	1920	2331	2742	3153	3964	4526	4853	5180
FY99 COST	134	269	452	687	1099	1510	1920	2331	2742	3153	3964	4526
ACTUALS												
FY99 OBS	n/a	n/a	1307	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
FY99 COST	n/a	n/a	630	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
VARIANCE												
FY99 OBS			208									
FY99 COST			178									

FY98 FINANCIAL PERFORMANCE

AI

RTOP	Guide-line	OBS Plan	OBS Actual	OBS Variance	Cost Plan	Cost Actual	Cost Variance
548-20	1863	1770	1851	81	1547	1509	-38
548-21	1500	1426	1432	6	1246	1189	-57
TOTAL	3363	3196	3283	87	2793	2698	-95